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G. K Shenoy
P. J. Viccaro
E. E. Alp
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UNDULATOR PERFORMANCE ON PEP STORAGE RING WITH DIFFERENT OPTICS*

INTRODUCTION

Various magnetic optics have been considered for PEP storage ring which can be used depending on the operational circumstances. The storage ring for example is operated around 14.5 GeV when high energy investigations are carried out in which the positron and electron beams collide. This is referred to as the colliding-beam optics (CBO) mode. The low-emittance optics (LEO) has been tested at 8 GeV which is very useful for numerous synchrotron radiation studies. In addition, a new lattice with damping wigglers has been proposed which can provide very low emittance. This is referred to as very low emittance optics (VLEO). These lattices also provide straight sections with different lengths varying from 6 m in the symmetry straight, to 14 or 117 meters in the interactions regions which in principle would permit installation of very long undulator insertion devices for special applications. Our ability to profitably utilize the radiation from these undulators proposed for PEP is determined by their performance in the different operating modes and by whether the design tolerance required for acceptable operation of the device can be met with available technology.

The purpose of this paper is to provide spectral characteristics for some typical devices calculated using a Monte-Carlo algorithm in which the Lienard-

Wiechert potential is integrated over the trajectory of the charged particle along the undulator length. The actual emittance of the particle beam for the various PEP operating modes (see Table 1) are included explicitly in the simulations. In addition, we have carried out a single partial analysis of the effects of undulator magnetic field errors on the spectral properties in order to estimate the design tolerance requirements necessary for devices which have been proposed PEP.

TABLE 1

Optics	ε_x m-rad	ε_y m-rad	σ_x μm	σ_y μm	σ_x' μrad	σ_y' μrad
CBO (14.5 GeV)	117	12	2443	240	48	47
LEO (8 GeV)	8.2	0.8	749	287	11	3
VLEO (8 GeV)	1.9	0.2	205	8	9	24

UNDULATOR SPECTRAL PROPERTIES

At present there are two undulators installed on PEP, each approximately 2 m long and with 26 periods of length 7.7 cm. One of these devices has operated in both the 8 GeV LEO and 14.5 GeV CBO modes. At the higher ring energy, the first harmonic radiation is between 10 and 20 keV depending on the magnetic gap. The spectral on-axis brilliance for this undulator in the 8 GeV LEO mode is shown in Fig. 1. In this case, the first harmonic energy ranges between approximately 3 and 6 keV for the magnet gaps shown. The minimum magnet gap (4 cm) determines the smallest achievable first harmonic energy. At present this closed gap is the smallest possible with the present ID vacuum chamber installed on the PEP ring.

Higher first harmonic energies in the range of 10 to 20 keV at 8 GeV can be realized by using a devices with a period smaller than 7.7 cm. The performance of one such undulator with a period of 3.3 cm is shown in Fig. 2 for PEP operated in the LEO mode. The length of this device is approximately the same as the 7.7 cm one and contains 60 periods.

As can be seen, the on-axis brilliance is appreciable at all photon energies for the shorter period device. However, a smaller operating magnetic gap in the range of 1.5 to 2.0 cm is necessary. This means than an ID vacuum chamber with a vertical height is required which is smaller than the present one installed on PEP.

Fig. 3 compares the peak on-axis brilliance verses first harmonic energy for the 7.7 cm undulator in the LEO mode and the 3.3 cm device in the LEO and VLEO modes at 8 GeV. In the VLEO mode, a spectral brilliances exceeding 10^{19} pk/s/0.1%BW/mm^2/mrad^2 can be expected for the shorter period device. A similar comparison is made for third harmonic radiation in Fig. 4. As is evident, appreciable brilliance for this component is achievable with the 3.3 undulator in both the LEO and VLEO modes up to photon energies of 4 keV.

RANDOM UNDULATOR MAGNETIC FIELD ERRORS

As is known, [1-3], random errors in the undulator magnetic field is detrimental to the performance of the device. The main effect is to reduce the photon intensity in the harmonics. For the same rms magnetic field error, the reduction in intensity increases with the increasing harmonic number and depends on the total number of periods contained in the undulator. Results of a single particle analysis for the normalized intensities of the first and third harmonics as a function of rms field error are shown in Figs. 5 and 6, respectively. As can be seen, severe intensity reductions in both harmonics can be expected for devices with rms field errors greater than 0.5% and number of periods greater than approximately 400. This value for the rms field error has been achieved and even surpassed for several short (~ 2m) devices. However, it is clear that meeting the tolerance requirements for long undulators will require special effort and construction techniques. These factors must be included if a realistic evaluation of the performance of long undulators is to be made. For undulators with less than 100 periods, the magnetic field tolerance is not critical.

REFERENCES

1. B. Kincaid, J. Opt. Soc. Amer. B, 2 (1985) 1294.
2. J. M. Slater, presented at the 1987 Particle Accelerator Conference, Washington, D.C.; in press, IEEE Trans. Nucl. Science.
3. E. E. Alp and P. J. Viccaro, presented at the 5th National Conference on Synchrotron Radiation Instrumentation, Madison, WI, 1987; in press, Nucl. Inst. Methods.

FIGURE CAPTIONS

Fig. 1 On-axis brilliance verses photon energy for the 7.7 cm undulator at the two magnet gaps specified on the PEP storage ring operating at 8 GeV in the LEO mode. The simulation include the emittance given in Table 1.

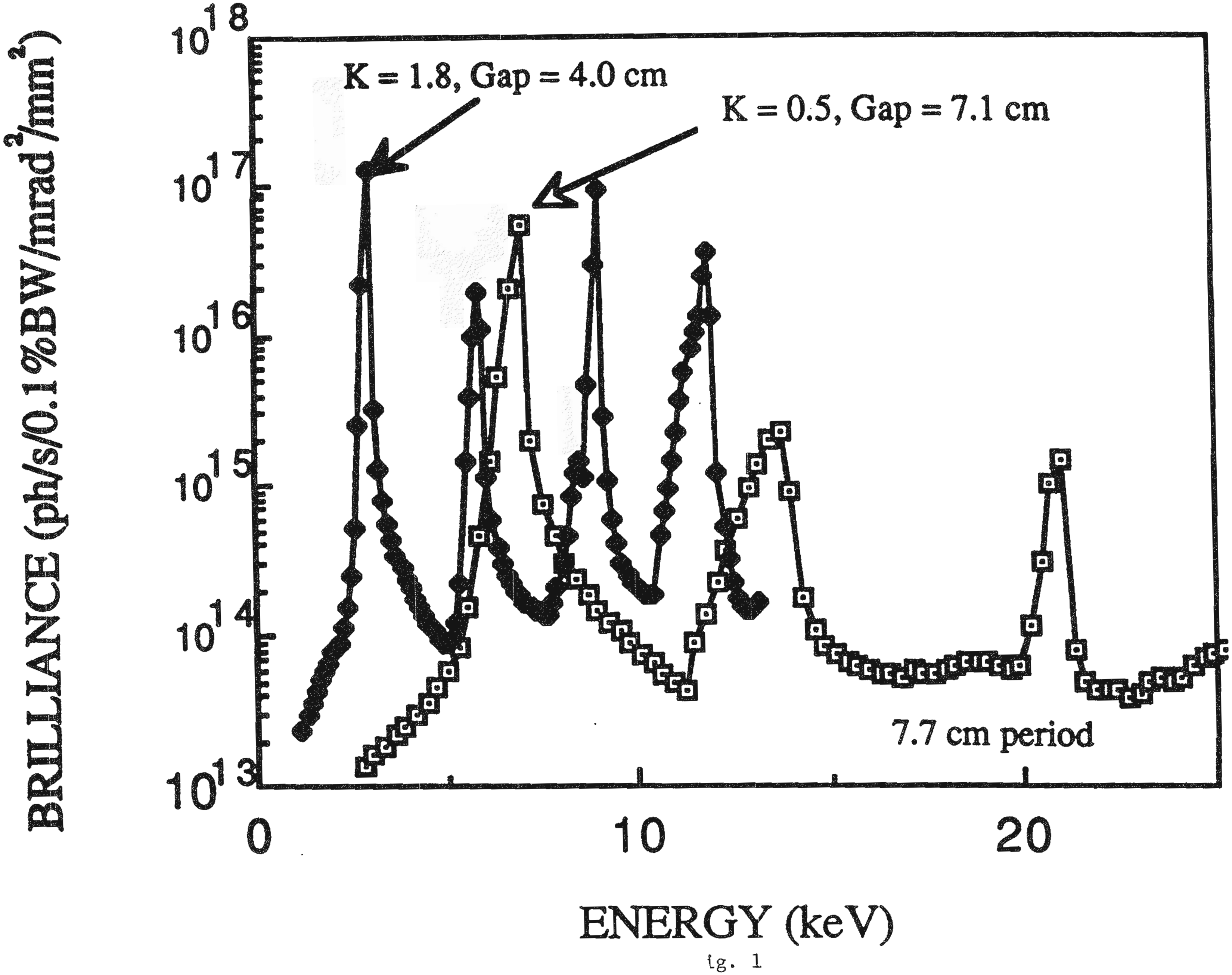
Fig. 2 On-axis brilliance verses photon energy for a 3.3 cm-60 period undulator on the PEP storage ring operating at 8 GeV in the LEO mode. The simulation includes the emittance given in Table 1.

Fig. 3 The peak on-axis first harmonic brilliance verses photon energy for the 7.7 cm device in the LEO mode and the 3.3 cm device in the LEO and VLEO modes at 8 GeV. The calculation includes the emittance values given in Table 1.

Fig. 4 The peak on-axis third harmonic brilliance verses photon energy for the 7.7 cm device in the LEO mode and the 3.3 cm device in the LEO and VLEO modes at 8 GeV. The calculation includes the emittance in Table 1.

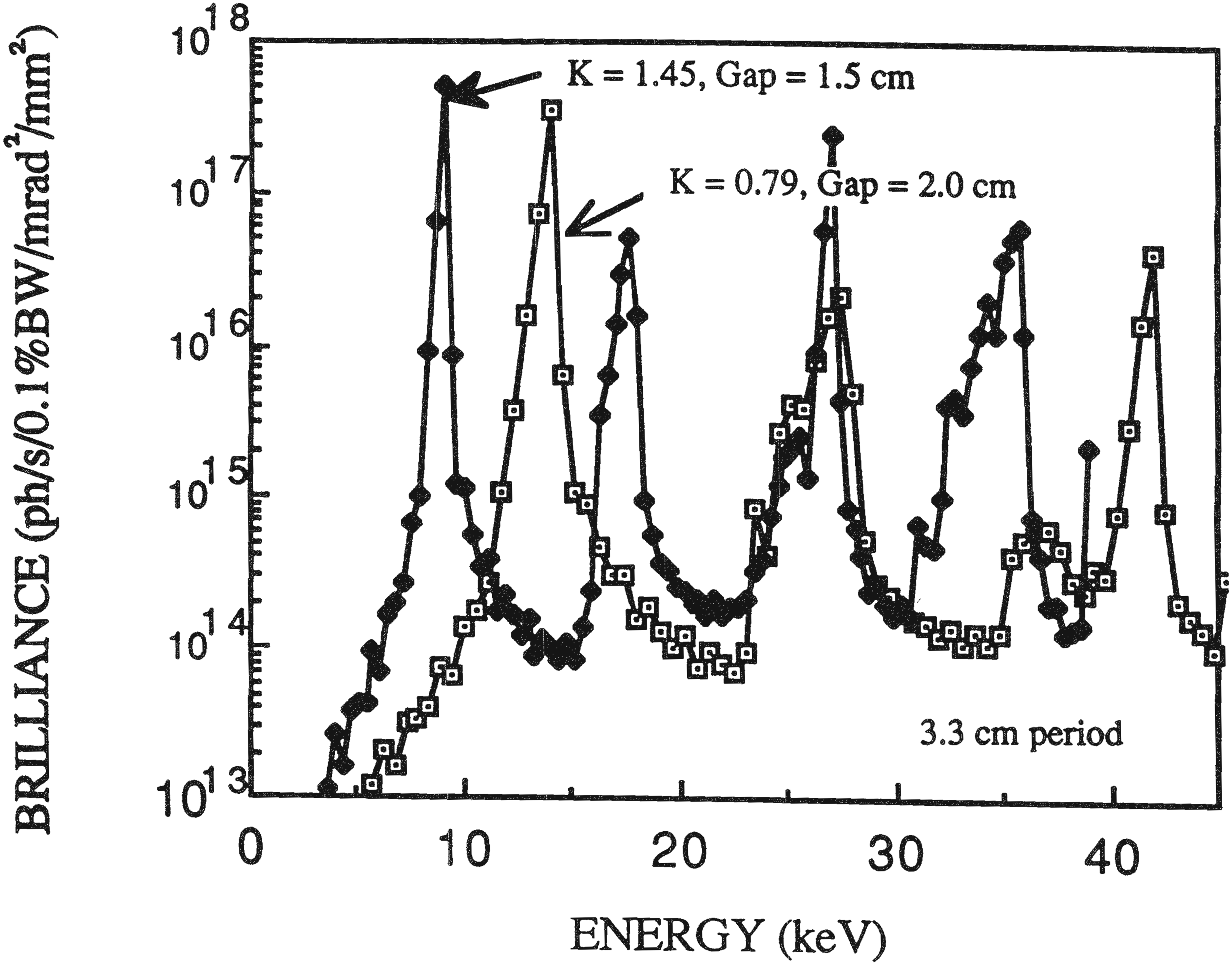
Fig. 5 The normalized peak on-axis first harmonic intensity verses rms undulator magnetic field error obtained from a single particle analysis. Each curve is calculated for an undulator with the total number of periods shown in the figure.

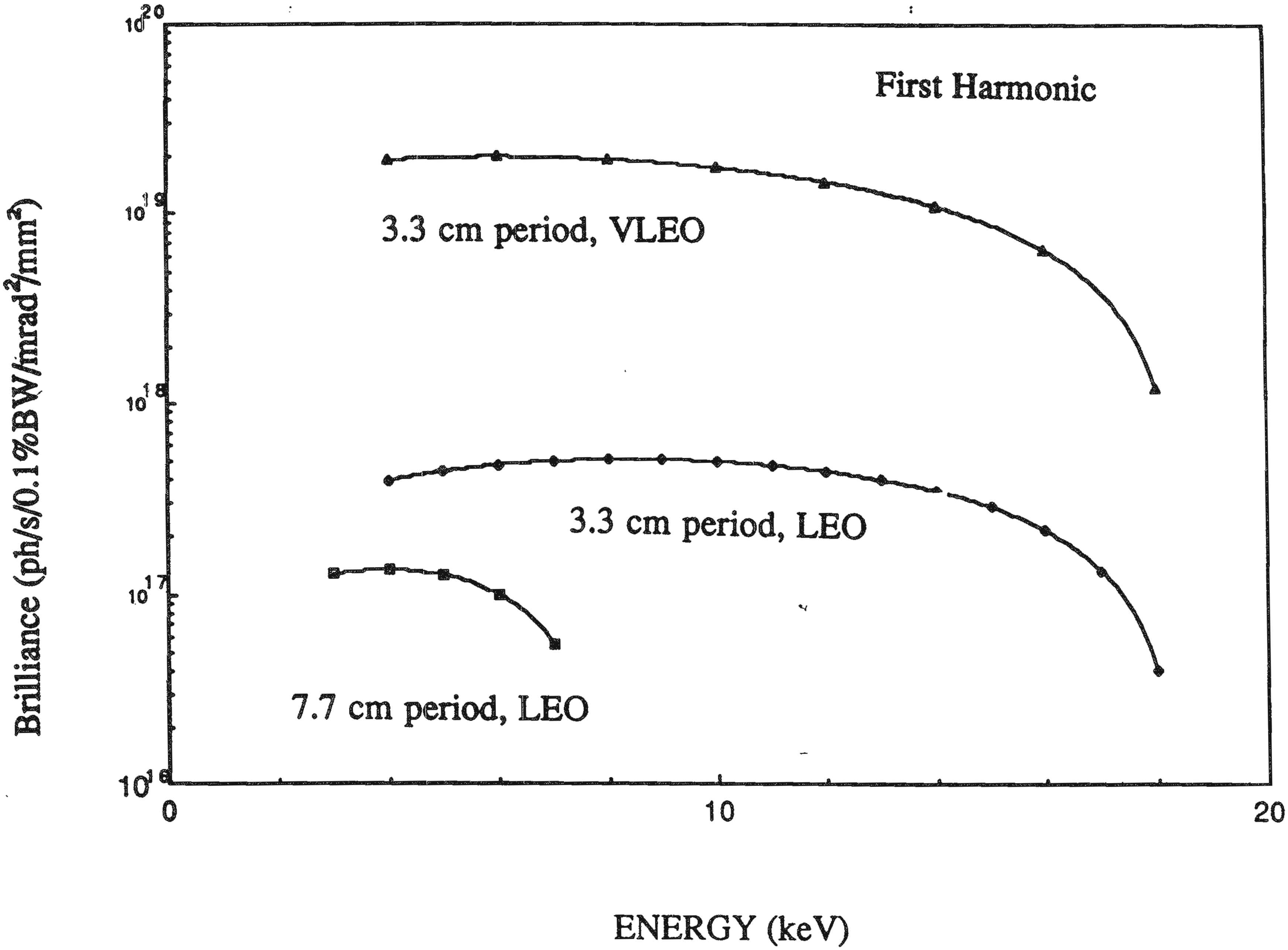
Fig. 6 The normalized peak on-axis third harmonic intensity verses rms undulator field error obtained from a single particle analyses for undulators. Each curve is calculated for an undulator with the total number of periods shown in the figure.



BRILLIANCE (ph/s/0.1%BW/mrad^2/mm^2)
10^{18}
10^{17}
10^{16}
10^{15}
10^{14}
10^{13}
K = 1.8, Gap = 4.0 cm
K = 0.5, Gap = 7.1 cm
7.7 cm period
0
10
20
ENERGY (keV)

ig. 1


BRILLIANCE (ph/s/0.1%BW/mrad^2/mm^2)
10^{18}
10^{17}
10^{16}
10^{15}
10^{14}
10^{13}
0
10
20
30
40
ENERGY (keV)
K = 1.45, Gap = 1.5 cm
K = 0.79, Gap = 2.0 cm
3.3 cm period
Fig. 2



First Harmonic
3.3 cm period, VLEO
3.3 cm period, LEO
7.7 cm period, LEO
Brilliance (ph/s/0.1%BW/mrad²/mm²)
10^20
10^19
10^18
10^17
10^16
0
10
20
ENERGY (keV)

g. 3

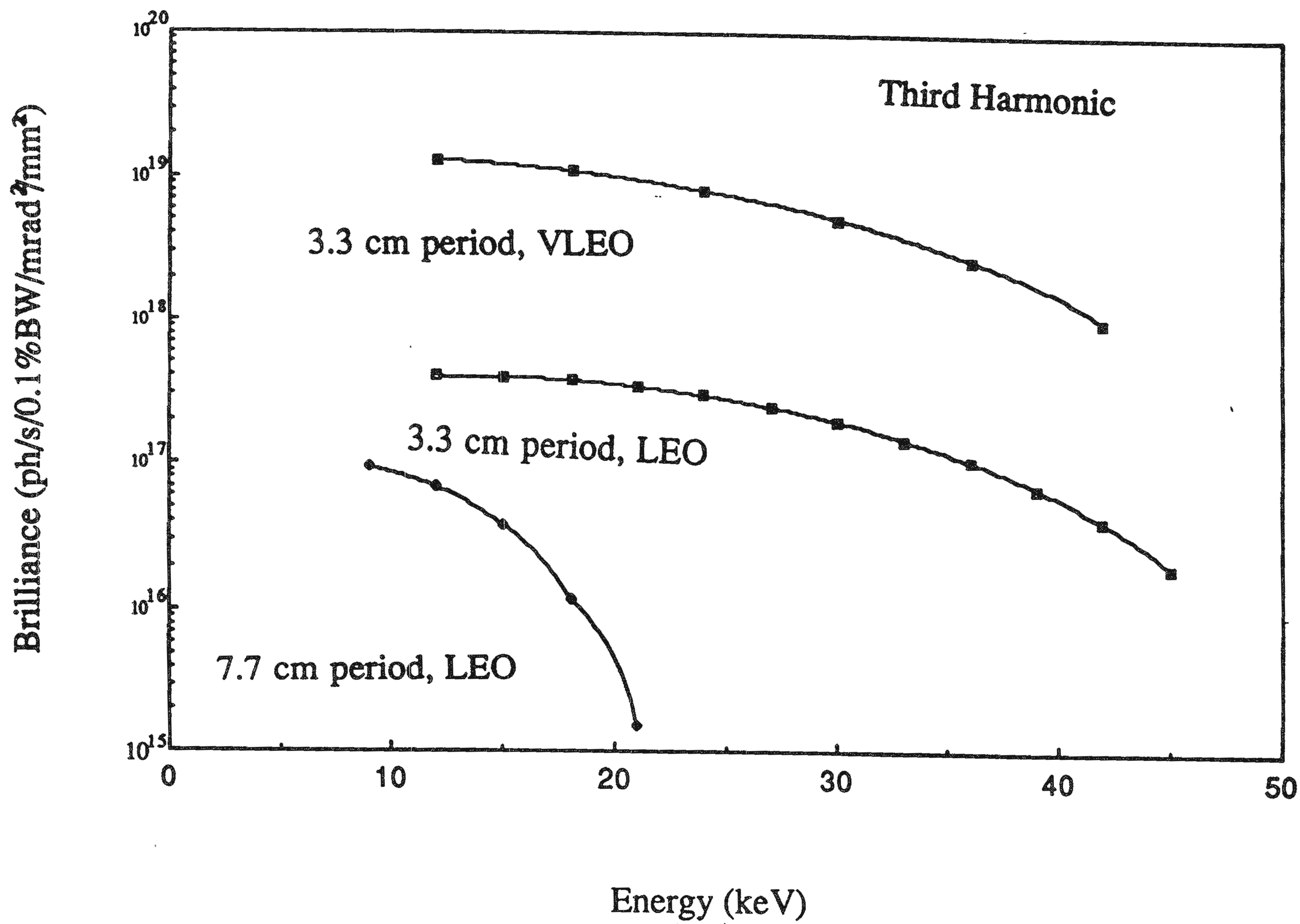

Brilliance (ph/s/0.1%BW/mrad²/mm²)
Energy (keV)
Third Harmonic
3.3 cm period, VLEO
3.3 cm period, LEO
7.7 cm period, LEO
10^20
10^19
10^18
10^17
10^16
10^15
0
10
20
30
40
50

Fig. 4

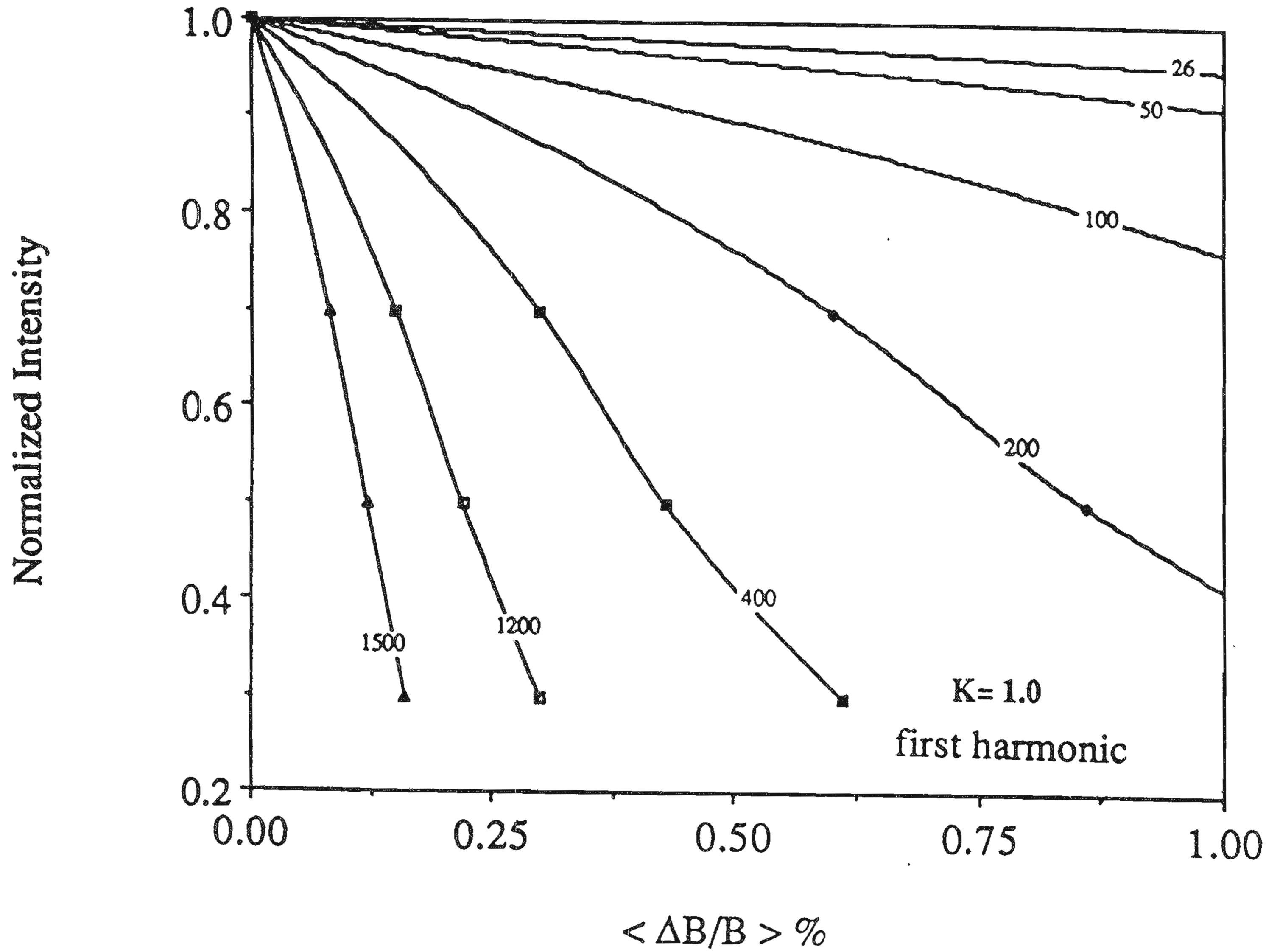

Normalized Intensity
1.0
0.8
0.6
0.4
0.2
0.00
0.25
0.50
0.75
1.00
26
50
100
200
400
1200
1500
K= 1.0
first harmonic
< ΔB/B > %

Fig. 5

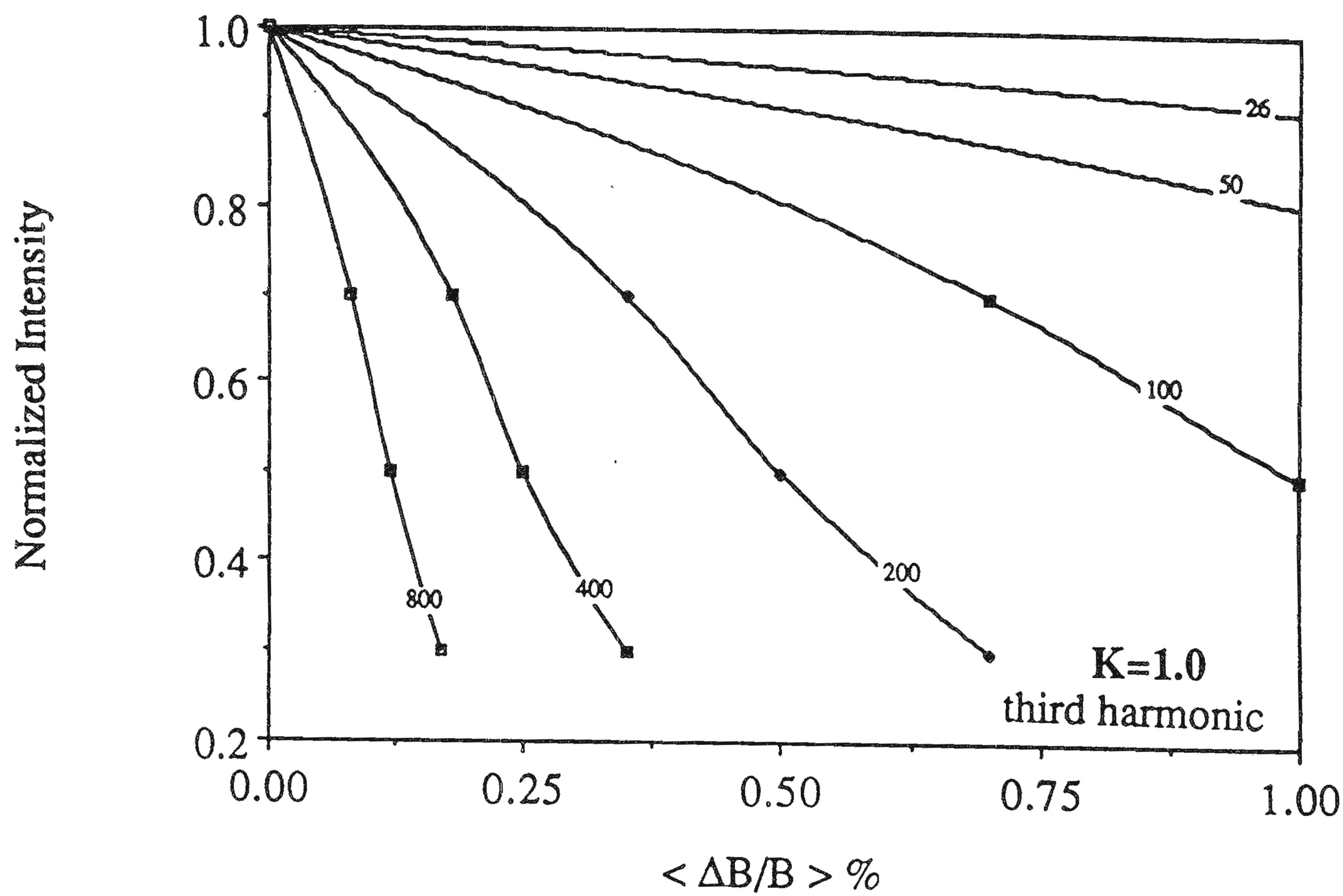

Normalized Intensity
1.0
0.8
0.6
0.4
0.2
0.00
0.25
0.50
0.75
1.00
26
50
100
200
400
800
K=1.0
third harmonic
< ΔB/B > %

Fig. 6